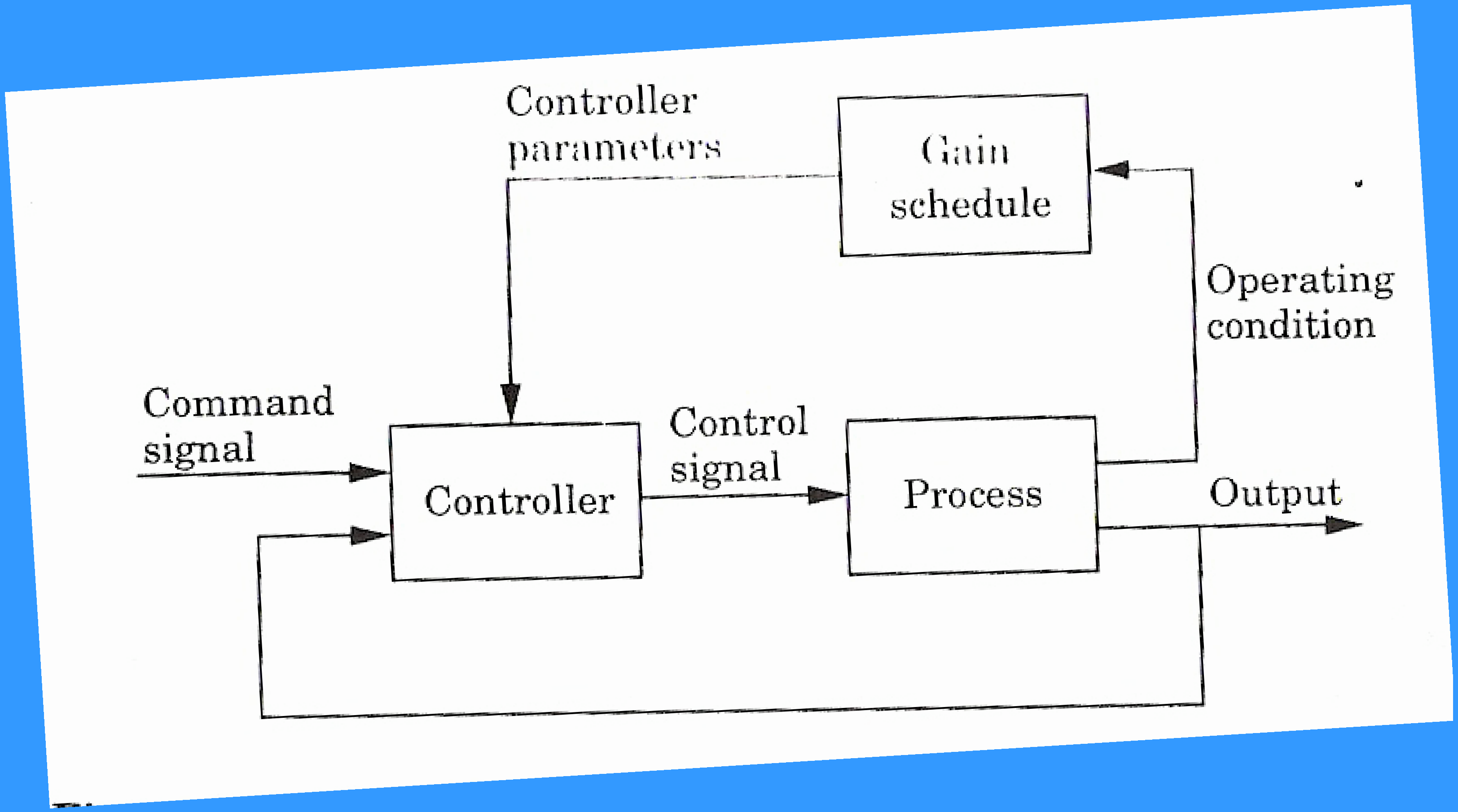
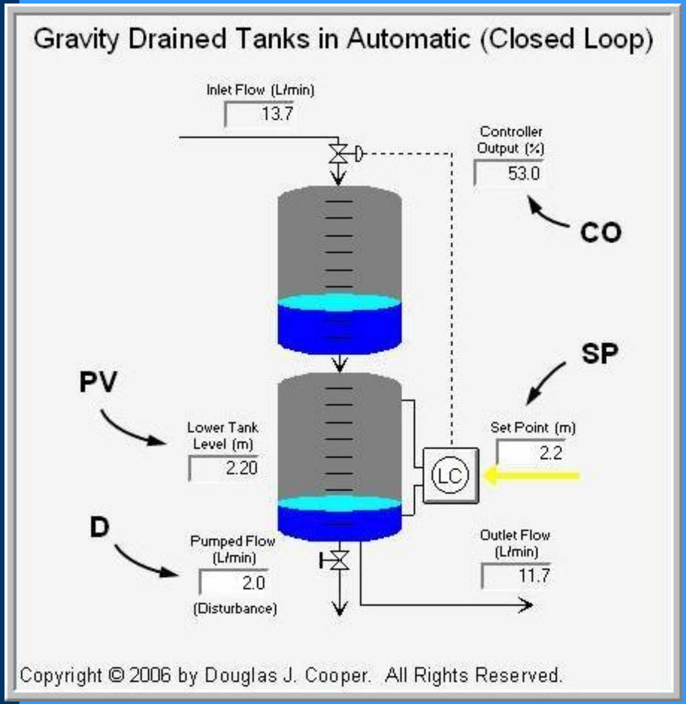
Gain Scheduling

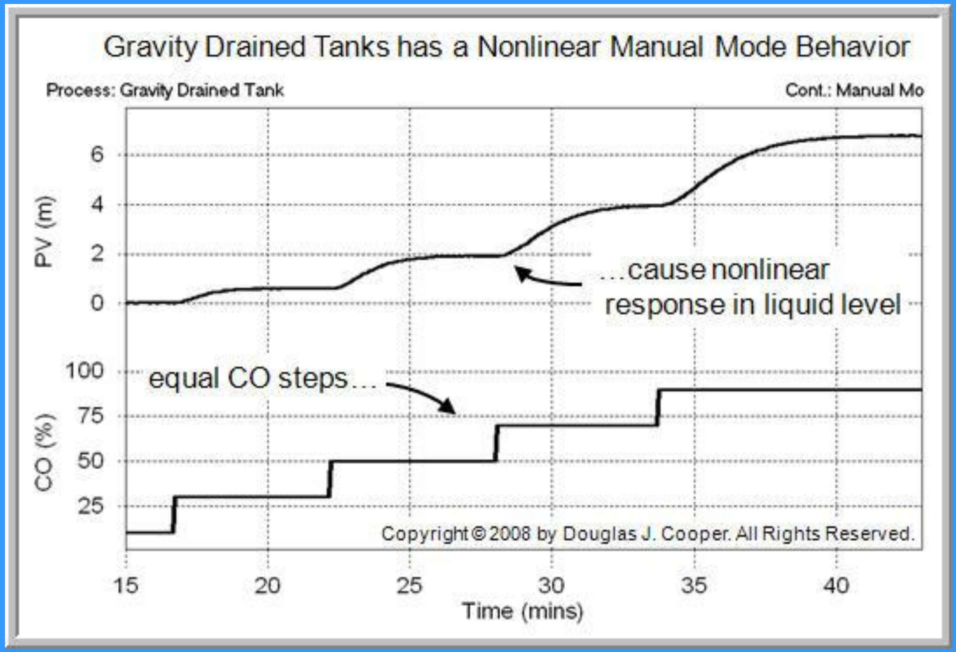
Não Linearidades



Não Linearidades

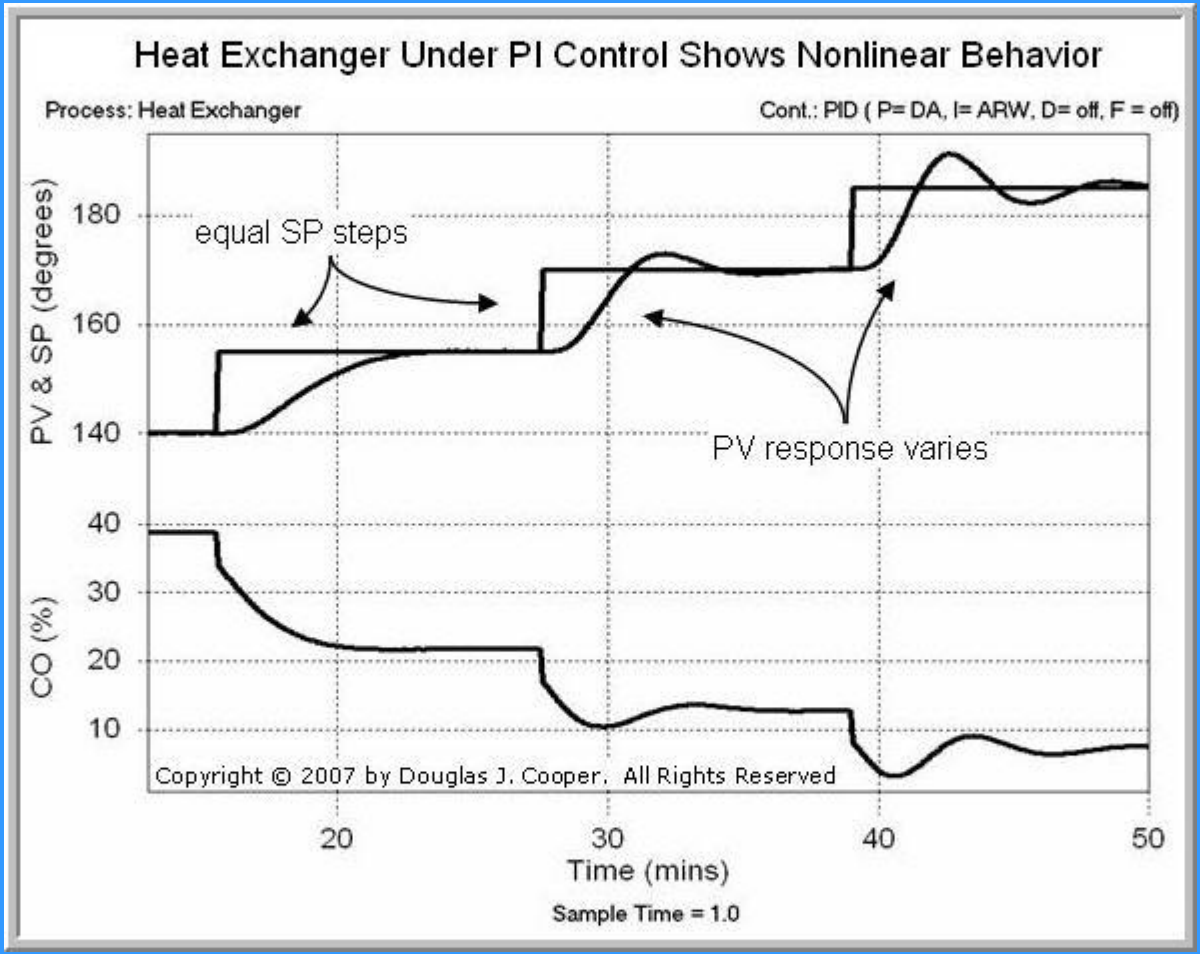
Ganhos do processo variáveis com ponto de operação





Não Linearidades

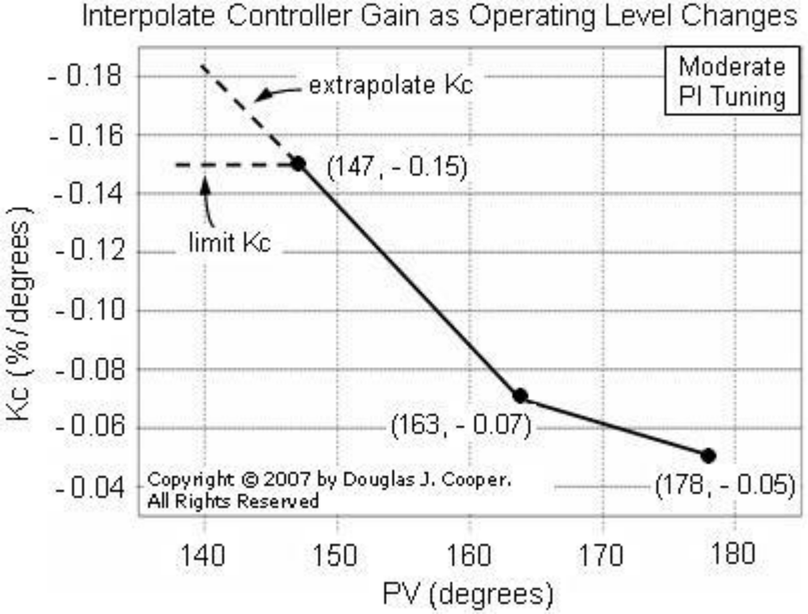
Ganhos do processo variáveis com ponto de operação



Não Linearidades

Ganhos do processo variáveis com ponto de operação

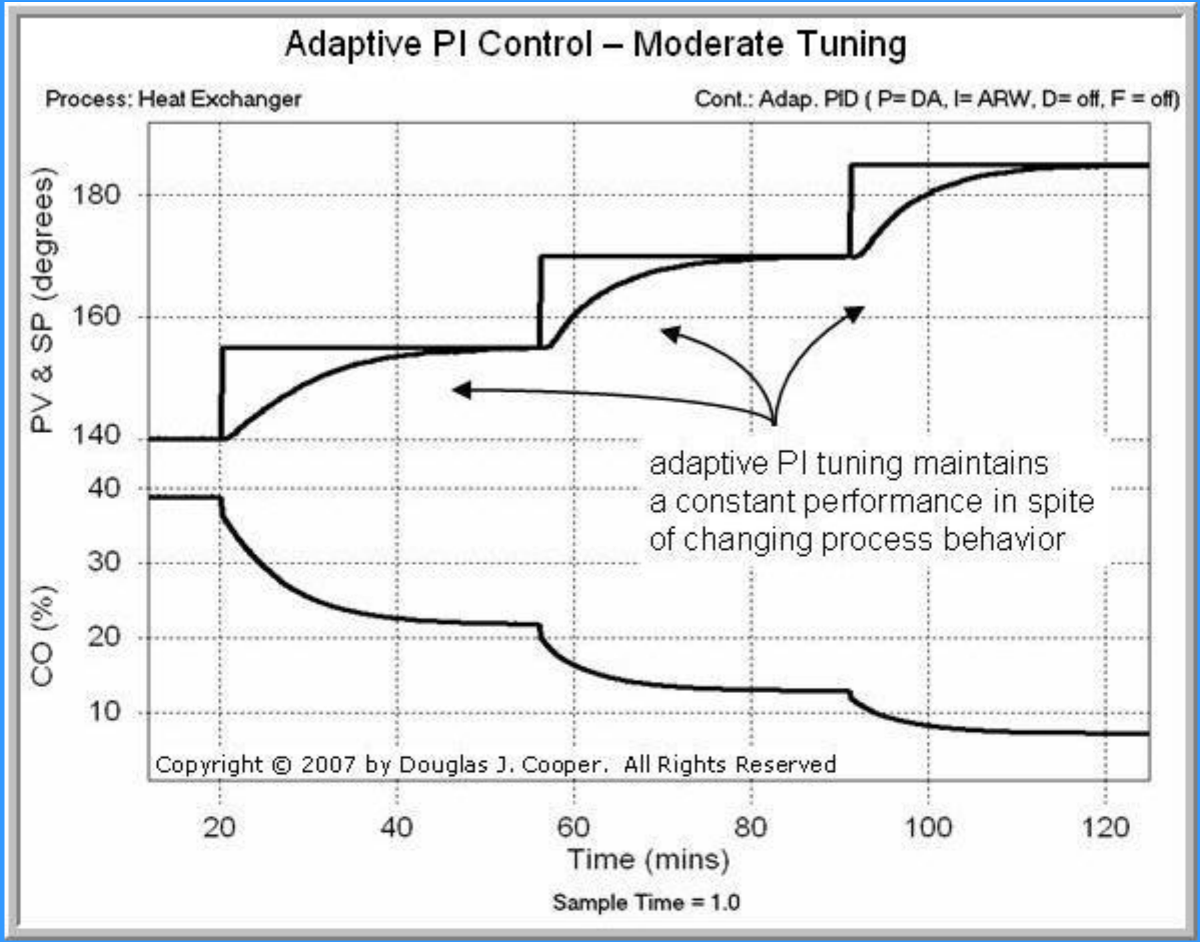
SOLUÇÃO POSSÍVEL: GAIN SCHEDULING



Não Linearidades

Ganhos do processo variáveis com ponto de operação

SOLUÇÃO POSSÍVEL: GAIN SCHEDULING



Caso 2 – Válvula não linear

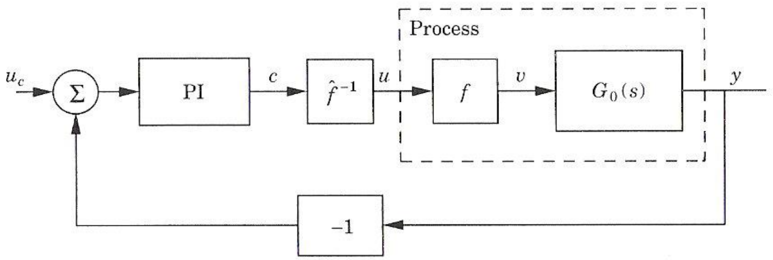


Figure 9.2 Compensation of a nonlinear actuator using an approximate inverse.

EXAMPLE 9.1 **Nonlinear actuator**

Consider the system with a nonlinear valve in Example 1.4. The nonlinearity is assumed to be

$$v = f(u) = u^4 \qquad u \geq 0$$

Let $\hat{f}^{-1}$ be an approximation of the inverse of the valve characteristic. To compensate for the nonlinearity, the output of the controller is fed through this function before it is applied to the valve (see Fig. 9.2). This gives the relation

$$v = f(u) = f\left(\hat{f}^{-1}(c)\right)$$

where c is the output of the PI controller. The function $f(\hat{f}^{-1}(c))$ should have less variation in gain than f. If $\hat{f}^{-1}$ is the exact inverse, then $v = c$.

Assume that $f(u) = u^4$ is approximated by two lines (see Fig. 9.3): one connecting the points (0, 0) and (1.3, 3) and the other connecting (1.3, 3) and

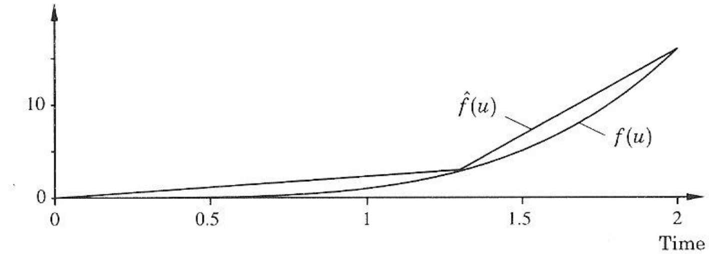
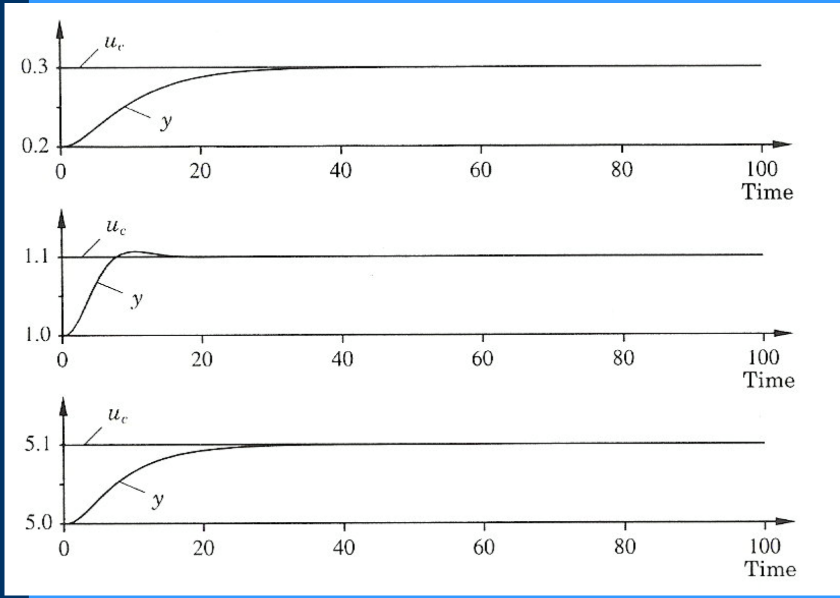


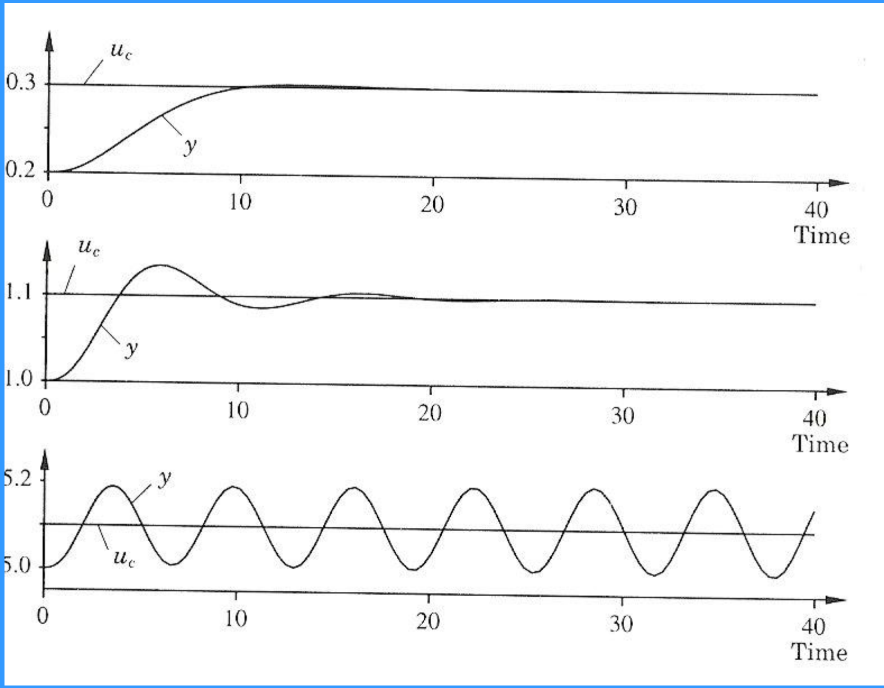
Figure 9.3 The nonlinear valve characteristic $v = f(u) = u^4$ and a two-line approximation $\hat{f}(u)$.

Não Linearidades

Gain Scheduling



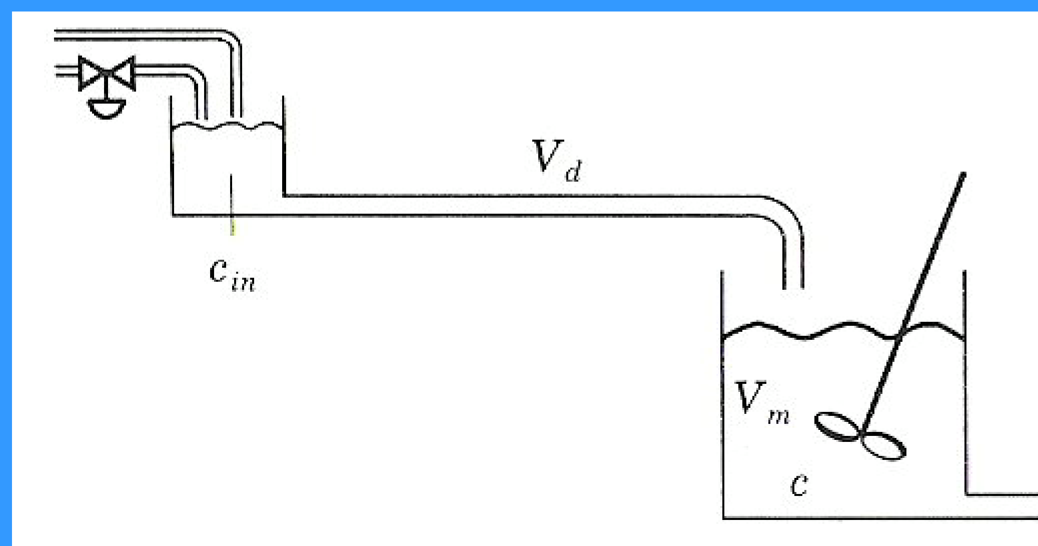
PI ganhos fixos



$$G(s) = \frac{1}{1 + sT} e^{-s\tau}$$

$$T = V_m/q \qquad \tau = V_d/q$$

Caso 3 – Controle de Concentração



Não Linearidades

Caso 3 – Controle de Concentração

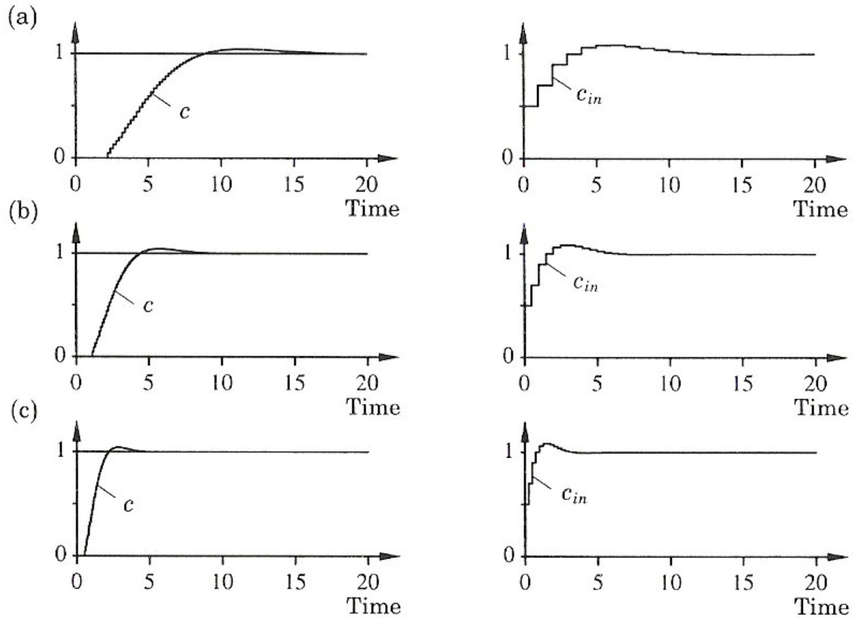


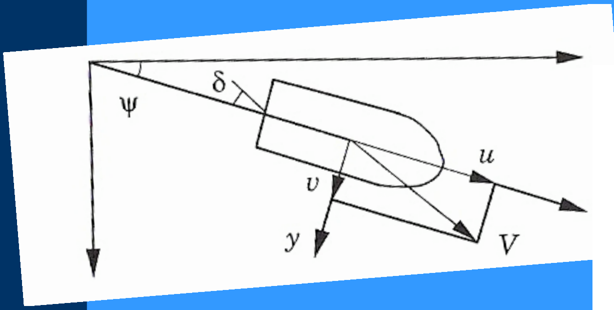
Figure 9.5 Output concentration and control signal when the process in Example 9.3 is controlled by a fixed digital controller but the sampling interval is $h = 1/(2q)$. (a) $q = 0.5$; (b) $q = 1$; (c) $q = 2$.

implement this gain-scheduling controller, it is necessary to measure not only the concentration but also the flow. Errors in the flow measurement will result in jitter in the sampling period. To avoid this, it is necessary to filter the flow measurement.

The Ziegler-Nichols transient response method discussed in Section 8.4 is based on a model with a time delay and a first-order system. Table 8.1 gives

$$K_c = \frac{0.9\tau}{T} = \frac{0.9V_d}{V_m}$$

$$T_i = 3\tau = \frac{3V_d}{q}$$



Caso 4 – Piloto automático de navio

EXAMPLE 9.6 **Ship steering**

Assume that the ship steering dynamics can be approximated by the Nomoto model of Eq. (9.12) and that a controller of PD type with the transfer function

$$G_r(s) = K(1 + sT_d)$$

is used. The loop transfer function is

$$G(s)G_r(s) = \frac{Kb(1 + sT_d)}{s(s + a)}$$

The characteristic equation of the closed-loop system is

$$s^2 + s(a + bKT_d) + bK = 0$$

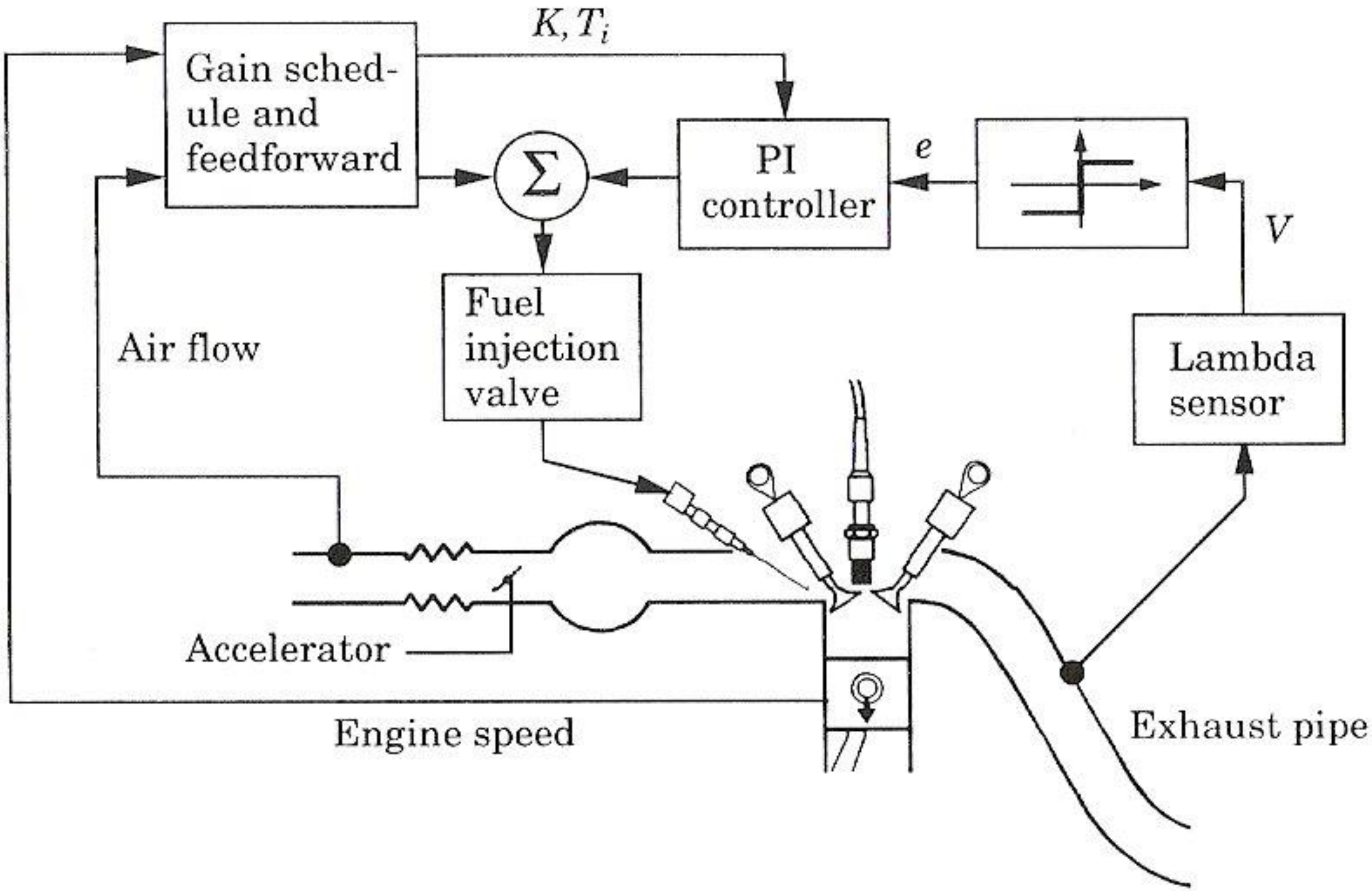
The relative damping is

$$\zeta = \frac{1}{2}\left(\frac{a}{\sqrt{bK}} + T_d\sqrt{bK}\right)$$

The damping will depend on the speed of the ship. Assume that the model of Eq. (9.12) has the values a_{nom} and b_{nom} at the nominal speed u_{nom}. The variable u_{nom} is the nominal velocity used to design the feedback. Assume that u is the actual constant velocity. Using the speed dependence of a and b given by Eqs. (9.13) gives

$$a = a_{\text{nom}} \frac{u}{u_{\text{nom}}}$$

$$b = b_{\text{nom}} \left(\frac{u}{u_{\text{nom}}}\right)^2$$



Caso 5 – Injeção eletrônica

Não Linearidades

WT155

Gain Scheduling and Auto-Tuning

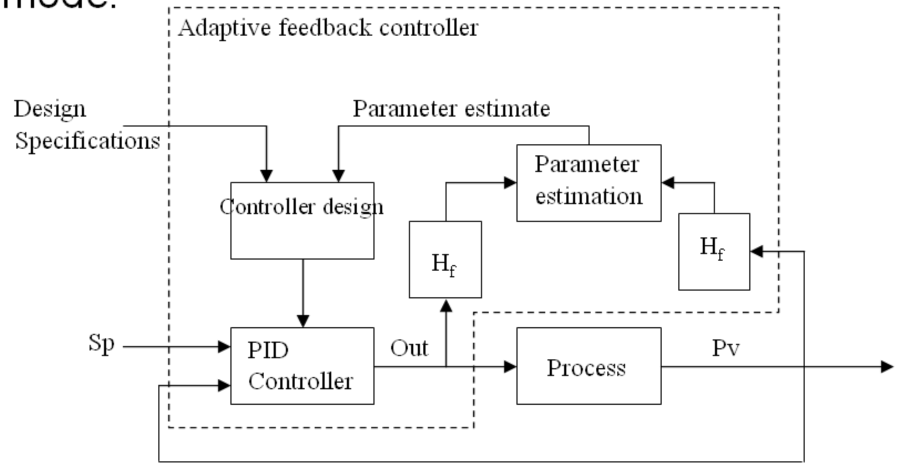
- Maximum 5 parameter zones
- Auto-Tuning in each zone, i.e. as described before
- Reference signal for the zones
  - Either PV, Out, SP or an external signal
  - Zone limit values should reflect process dynamic areas that need different tuning constants
- Transfer between zones are bumpless
- Transfer between zones have built in hysterisis that is automatically calculated, i.e. related to the range of the zone to be entered

Não Linearidades

Adaptation of the control parameters can be used when the dynamic changes are slow in comparison with the main process dynamics!

A variety of rule sets defines when the Out and Pv signals can be used for adaptation and then the parameter estimate is focused around the frequency gained during the auto-tuning. Parameter estimation is done using Least-Squares methods.

Adaptation runs continuously and an extensive set of rules are implemented to safe-guard against condition when Out and Pv does not contain useful modelling information contents or the controller is in manual mode.



Outra Solução – Controle Adaptativo

Não Linearidades

Adaptation of the control parameters can be used when the dynamic changes are slow in comparison with the main process dynamics!

A variety of rule sets defines when the Out and Pv signals can be used for adaptation and then the parameter estimate is focused around the frequency gained during the auto-tuning. Parameter estimation is done using Least-Squares methods.

Adaptation runs continuously and an extensive set of rules are implemented to safe-guard against condition when Out and Pv does not contain useful modelling information contents or the controller is in manual mode.